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DEVELOPMENT OBJECTIVE

HIGH PRECISION STEREO COMPARATOR

1. Introduction

This development objective outlines requirements for the design and fabrication of an advanced state-of-the-art high precision stereo comparator.

2. Concept

The program is to be accomplished in three distinct phases:

2.1 A design phase, to investigate the various areas in optics, electronics, and mensuration principles upon which the development is based and submit for approval a design concept.

2.2 Fabrication of the equipment resulting from the design concept approval.

2.3 Test and evaluation of the comparator upon completion. This portion of the program will be accomplished primarily at the contractors facility but final test, evaluations and acceptance will be conducted at the Customer's facility after installation.

3. General Description

This comparator shall consist of a high performance stereo viewing, stereo measuring (4 axes) comparator, utilizing cut film and roll film in widths up to 9½" wide and up to 500 foot rolls. The optical system shall provide means whereby large range differences in scale between the conjugate images may be accommodated. A continuously variable, high resolution, zoom-type system, coupled with automatically controlled interchangeable elements, providing a continuous magnification range of 10x to 200x is required. The optical system must provide the operator with scanning capability over a large stereo image area without movement of the eye station. The system must provide direct (non-optical) overall viewing of the entire format area in conjunction with the small area limited by the optical magnification. The overall stage format area must be no less than 9½" x 20" and the system must be capable of measuring between any two points within this format area. The coordinate data will be readout on operator command. Control of the photo stages shall be under operator's control through the use of a single joystick with 4 axes independent control through the use of handwheels. An optical feature for separate consideration is a completely automatic stereo correlation system as further described in the detailed requirements. If there are devices or subsystems which are not specifically listed as requirements, but which are believed to significantly contribute to the usefulness or ease of operation of the stereo comparator, they may be included as optional features in the proposal at the vendors discretion. Each optional feature should be individually priced.

4. Physical and Operational Considerations

The stereo comparator is to be designed to operate in a clean office type environment where a small amount of slightly corrosive chemical fumes from photo lab or similar operations may be present.

Special considerations must be given to reducing heat output and ambient noise in the system. Considerations: The following facilities will be available as requested:

1. Electricity: 110V 1 phase and 208V, 3 phase, 4 wire
2. Chilled water and tap water
3. Compressed air at 80 p.s.i.
4. Vacuum

Additional considerations must also be given to reducing Radio Frequency Emissions in accordance with Federal Spec 222. This specification is to be limited to information carrying emissions.

Design consideration must be given to producing the minimum overall package size.

5. Detailed Requirements

5.1 Overall Physical Considerations

5.1.1 The instrument is to be designed to operate in a room 15' x 18' including all components, personnel, workspace, etc.

5.1.2 The maximum size of any single component is not to exceed 47" x 95" x 80" high for shipping and installation purposes.

5.1.3 Environmental conditions within the room will be held to temperatures of 72° F $\pm$ 5° F and humidities of 55% + 15% - 5%. Dust particles larger than $\overline{2}5$ microns will be filtered by the air conditioning system. However, reasonable precaution must be taken in the selection of components to allow tolerances for photo lab and other component fumes in the air.

5.1.4 Provisions must be made for maximum personnel protection from toxic fumes or other safety hazards that may be generated by the equipment.

5.1.5 The manufacturer is to assume responsibility for all facility hook up from the point where the facilities may enter the room.

5.1.6 If the stereo comparator or any component is vibration sensitive so as to adversely affect performance, adequate vibration isolation must be incorporated in the design.

5.1.7 The physical layout of the comparator and associated equipment is to be so designed that the operator can reach all normal operational controls from the operator's work station.

5.1.8 Sufficient clearance is to be maintained so that the operator can raise or lower his chair height ± 2" so as to place his eye level in a comfortable position with respect to the eyelens station without being restricted by other physical considerations such as leg room.

5.2 Viewing Conditions.

5.2.1 Image magnification shall be continuously variable from 10x to 200x. This may be accomplished through the automatic insertion or exchange of elements; three such exchangeable elements have proved to be adequate in other instruments. The ranges of these magnification stages must be such that there shall be a minimum overlap of 5x at each stage. Magnification changes shall not be accomplished through interchange of eyelenses, (oculars). Both the real and apparent fields shall approximate that of high performance microscope design at all powers. The optical trains shall be capable of independent or unison magnification control. The system shall be parfocal at all magnification settings. Independent focus control shall be available at each eyelens and each objective. The eyelens and objective angular fields are to be as wide as possible consistent with other requirements.

5.2.2 Viewing will be by microscope binocular eyepieces which will provide maximum operator comfort. The angular field of the eyelens station is to be at least 35° and special considerations are to be given to eye relief, exit pupil, and field flatness. The eyepieces shall be adjustable to include but not be limited to the following adjustments:

1. A fixed position irrespective of scan location with conveniently located exit pupils.

2. Adjustable interpupillary distance from 50mm to 75mm.

3. Adjustable headrest.

4. Adjustable tilt angle of approximately ± 10°.

5.2.3 Image quality available to the operator should, at all magnifications, approximate that of a high performance microscope with respect to: aberation corrections, field size, field flatness, contrast and resolution. The design goal for resolution shall be eight lines per millimeter per power at 10x, decreasing linearly to five lines per millimeter per power at 200x.

5.2.4 Image rotation shall be independently available for each image and be at least 360° of independent angular rotation. This shall not introduce dislocation or displacement with respect to the reticule.

5.2.5 A reticle or reference dot will be placed in each optical train as close to the objective lens as possible. The reticle is to be a dot of variable intensity and continuously variable in size from one-half second to four seconds of arc (at the eyelens exit pupil.) The dot is to be a perfect circle at all times with a sharp edge gradient.

5.2.6 An accessory anamorphic correction is to be provided for each optical train which shall be of a minimum ratio of 1:2. The optical quality is to be consistent with the overall design objectives. This accessory is to be easily removable since the majority of the work is to be accomplished without anamorphic distortion.

5.2.7 Each optical train will be furnished with an adjustable high intensity illumination source consistant with good optical practices and insuring that adequate intensity is available at all magnifications to insure reasonable intensity with densities as high as 3.0. Necessary care shall be taken to assure that the film is adequately cooled so as not to affect the measurement accuracy. Care shall be taken to assure that the illumination Kelvin temperature does not fall below 3400°K under any intensity level.

In addition to the illumination required for the optical train, a second illumination system shall be provided to fill the entire format stage area for general viewing. If this format illumination should conflict with requirements outlined elsewhere in this objective, it will under those circumstances be appropriately controlled, but under no circumstances be deleted.

5.2.8 Provision shall be made to provide for optical switching by reversing the eye/object station viewing relationship (left eye to right stage and right eye to left stage), and to provide binocular monoscopic viewing of eitherthe right or left stage.

5.3 Film Stage, Transport, and Hold-down System

5.3.1 The comparator shall consist of two 9½" x 20" film stages and accommodate formats varying from approximately 70mm sq. to 9½" x 20".

5.3.2 A vacuum hold down system is preferred with not more than 10 seconds required for pull down. Other techniques will be considered however. After the film is properly loaded, subsequent sealing, breaking, or vaccum, transporting and resealing must be accomplished automatically.

5.3.3 The film hold down system must accommodate cut chip film as well as roll film.

5.3.4 Adjustment for various width roll or cut film must be accomplished within two minutes.

5.3.5 When clamped, the film must be maintained in sharp focus throughout the entire possible format movement at all magnification settings.

5.3.6 The film stage system must be capable of handling roll film which may vary in widths from 70mm to $9\frac{1}{2}$ inches and be capable of handling any width within this range whether presently manufactured or not. The weight of the roll film drive mechanism, etc., shall be supported elsewhere than on the main film stage. Provision shall be made to handle up to 500 foot rolls of film within the specified widths.

5.3.7 Each stage is to have its own independent film transport system. The transport system will be motorized with a variable speed range of approximately .5 inches per second to 250 feet per minute. The transport shall be designed to insure that proper film tension is maintained at all times and guarantee that maximum protection is assured against abrasions, scratches and tearing.

5.4 Film Measurement System.

5.4.1 The minimum accuracy required over the full $9\frac{1}{2}$" x 20" format travel is one part in 20,000, with a design goal of one part in 100,000 (approximately ± 5 to ± 25 over 20"). The least count or pulse increment required is approximately ± $\frac{1}{2}$ micron, with a design goal of approximately ± $\frac{1}{4}$ micron. A straight metric counting system is desired, but other incremental systems will be acceptable.

5.4.2 The accuracy stated above refers to total readout repeatability accuracy and includes electronic errors, temperature drift, etc. It does not include operator pointing accuracy. In addition, the engine ways must be straight and orthogonal to 2 seconds of arc (9.7×10^{-6} radians), i.e., the ways must contribute less than ± 5 microns error to a measurement over 20 inches of travel and less than ± $2\frac{1}{2}$ microns error to a measurement over $9\frac{1}{2}$ inches of travel. The objective of this program is to produce the highest practical local accuracies (areas up to 2 inches sq.) with lesser emphasis on accuracies over longer dimensions.

5.4.3 All forms of transducer systems (translating stage linear motion into digital information) must be considered, with special emphasis on non-ambiguous systems, i.e., scale interpolation techniques as compared to ambiguous pulse generating systems.

5.4.4 The measuring engine drives must be capable of rapid traverse from one point to another without affecting measuring accuracy, and shall be continuously variable. The minimum acceptable slew rate range is 3" per second to .03" per second.

5.4.5 To achieve high pointing accuracy, slow drive speeds are required that are free of overshoot or backlash, and assure a pointing accuracy of ± $\frac{1}{2}$ the least resolvable increment of motion.

5.4.6 The drive controls for both slewing and fine positioning shall provide the capability for:

1. One common control for all four axis
2. Control for both axis of either film stage (or measuring engine).
3. Independent control of each axis.

The design of the system shall insure that the operator achieve the desired motion with a minimum of effort.

5.5 Measurement Readout System

5.5.1 The coordinate position of each of the four axes should be continuously presented to the operator on a seven digit display, plus sign if applicable. The coordinate information generating system shall also have a zero reset and preset capability.

5.5.2 In addition to the coordinate information, the following additional information shall be available as part of the readout message:

1. 10 each, eleven position rotary switches (twelve position switches with one position mechanically blocked,

2. five push-on solenoid hold and release switches and

3. sixteen push-on, push-off switches.

5.5.3 On command by the operator the coordinate information and auxiliary information described in par 4.5.2 will be readout, either into an IBM card punch or directly into a central computer. The Government has an existing design to accomplish the above task utilizing ambiguous pulse techniques. If non-ambiguous techniques are used, the existing design may be modified to accomplish the task. Procurement of the readout system will be made by the successful bidder and incorporated into the equipment.

5.6 Control Console.

5.6.1 In order to assure maximum flexibility of operations all controls shall be placed to allow operation by either left hand or right hand operation. It is suggested that a portable or moveable control console be considered.

5.6.2 Provision for an operator's work space, convenient to the operator's normal writing position is required. A portion of this area shall consist of a light table with variable illumination.

5.7 Auto Stereo Correlation.

5.7.1 Provision shall be made in the design phase for incorporating automatic stereo correlation in the comparator either in the initial fabrication or retrofiting at a later date.

5.7.2 The considerations for autostereo correlation shall include but not be restricted to:

1. large scale differences between the two photographs,
2. anamorphism within either one or both photos of the stereo-pair,
3. relative image rotation between the two photos.

5.8 Reliability and Service Time

5.8.1 The comparator and related equipment shall be designed to withstand operating service usage, under normal operating conditions, for a period of 5000 cumulative operational hours without degradation of performance, and with only minor maintenance due to normal mortality of expendable replacement parts.

5.8.2 To insure maximum of up-time a preventative maintenance program is to be established utilizing Government maintenance personnel where possible.

5.9 Security

5.9.1 Design considerations must be given to reducing the probability of detection of security information which may be emitted by mechanical electro-mechanical or electronic means, i.e., there should be no mechanical or electronic radiation detectable beyond 150 feet from the instrument.

5.10 Test Provisions

5.10.1 The contractor shall prepare and submit to the project monitor for approval a detailed test plan sixty days prior to completion of the instrument. This test plan shall specify and describe in detail those tests to be conducted both at the contractor's plant and the Government facility to determine conformance with requirements.

5.10.2 The contractor shall provide all test targets, test film, and test equipment to adequately demonstrate fulfillment of performance requirements and provide the Government with a calibration report. All test materials and equipment shall be detailed in the submitted test plan for approval.

6. Philosophy

Aside from the obvious complexity and sophistication required by the design objectives, it is required that this system embody all possible design ingenuity to accomplish these objectives with simplicity, compactness and maximum economy. Numerous approaches to the solution of this problem should be considered and evaluated by the contractor. Aborted approaches in design should be completely documented. In order that maximum efficiency and effectiveness be maintained, the successful bidder must express a willingness to subcontract those phases of the design and fabrication for which he does not have effective in-house capability.